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PRICING SOYBEANS

An Economic Appraisal of Alternative Methods

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Soybean growers, elevator operators, and processors could profit from a more accurate appraisal of soybean values than is obtainable through the present use of U. S. official grain standards. Although oil content is a major value-determinant of soybeans, the official grain standards do not take it into account in soybean grading. The oil content of 575 soybean samples ranged from 18.6 to 23.5 percent. If soybean oil is worth $12\frac{1}{2}$ cents per pound the variation in soybean product value (due to variation in oil content) would be equivalent to 36 cents per 60-pound bushel. An improved method of evaluating soybeans would enable farmers to market beans with high oil content at prices more nearly in line with their true value. Elevator operators and processors could gain by not having to pay as much for soybeans having lower oil content.

There is now available for soybean farmers and buyers a quick and relatively simple method for determining the oil content of soybeans at the time of sale. Two out of three times the results obtained by this method varied approximately 4 cents in value per bushel from the market value based on the official oil-analysis method. This new method, called the "dielectric method," 1/ utilizes electronic oil-testing equipment which permits nontechnical personnel after brief instruction to determine the oil content of individual samples within about 15 minutes. 2/ It can be used by the first buyers of the beans at elevators to determine oil content of the farmer's beans when delivered to the elevator, and at a substantial saving in cost and time per sample compared with the official gravimetric method now in use at oil mills and commercial laboratories. (A more precise comparison of the relative costs will be made in the final report.) While processors may analyze soybeans for oil

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1/ "Dielectric" refers to material that does not conduct electric current. When a dielectric material is placed between two electrodes a certain force exists which is a constant for a particular material. The addition of oil to a solvent results in a change in the dielectric constant which is proportional to the amount of oil added. The dielectric oil-tester (Steinlite LOS unit) measures these changes. Then prepared conversion tables are used to translate meter readings into the percentage of oil in soybeans.

2/ Hunt, W. H., Neustadt, M. H., Hart, J. R., and Zeleny, Lawrence. A Rapid Dielectric Method for Determining the Oil Content of Soybeans. Jour. Amer. Oil Chemists' Soc. 29(7): 258-261. 1952.

content, or obtain this service from commercial laboratories, elevator operators rarely, if ever, do. In any event, oil content is not used as a direct basis for purchasing soybeans from farmers.

The dielectric oil tester has been used to some extent in the trade for testing soybeans for oil content shortly before harvest to determine areas from which beans with high oil content can be expected. Also, it has been used for rapid testing of individual lots of soybeans arriving at the processing plant and for certain plant control work including the testing of press-cake for residual oil. While firms that have used the dielectric oil-tester generally regard it as useful for certain purposes, there have been variations in results obtained with it that have led to questions of whether or not to use it as an adjunct in grading at the farm market level.

The objective of the present study is to determine the economic feasibility of utilizing the dielectric oil-determining method to improve the grading and pricing of soybeans. This preliminary report is based on an analysis of data for the 1955-56 marketing year. A more detailed report will be published after the data for 1956-57 have been analyzed.

The monetary value of soybeans is governed in part by the quantities of oil and meal obtained from the soybeans. The outturns of oil and meal from a bushel of soybeans are generally about equal in value. However, a pound of oil is worth several times as much as a pound of meal. During the 1955-56 marketing season soybean oil was worth 4.7 times as much per pound as meal. During the following season (1956-57) the oil was worth 5.4 times as much per pound as meal. Currently, processors want soybeans with high oil content, and growers will be more interested in producing such beans if prices properly reflect the differences in the value of their components.

In terms of volume of output and of farm value, the soybean is the principal oilseed crop of the United States. The expansion of soybean production in this country has progressed at a phenomenal rate, particularly during the last 15 years. Domestic soybean production for 1941 was around 107 million bushels and valued at about $166,000,000, while for 1956 it was around 450 million bushels and valued at about $980,000,000.

The rapid growth of the soybean industry has been enhanced by the development and adoption of improved farming practices, more efficient processing techniques, and the ability of expanding markets to absorb the products of soybeans at competitive prices. The initial processing of soybeans separates the two principal components, oil and meal. These two products are then further processed to produce hundreds of other products for edible purposes and for industrial uses.

The relationship between laboratory-determined soybean oil content and oil content estimates based on official grade factors is discussed at this point to provide a basis for comparing the relative merits of the dielectric method in evaluating farmers' soybeans.

Evaluating Soybeans by Use of Official Grade Factors

The oil content of 55 soybean samples selected at random at the 3 test sites was estimated from the following grade factors: Test weight, and percentages of moisture, split soybeans, and foreign material per bushel of soybeans. Damage as a grade factor was not included because there were not enough damaged beans for comparable analysis. Two out of three estimates, 3/ based on the above soybean grade factors, came within 0.51, 0.45, and 0.42 percentage points, respectively, of the oil content determined at the commercial laboratory (table 1). These percentage points of oil converted to weight per 60-pound bushel represent differences between locations of 0.30, 0.27, and 0.25 pounds of oil between the oil estimates and the laboratory-determined oil content. If oil is worth 12½ cents per pound, these differences would represent values of 3.8, 3.4, and 3.1 cents, respectively, per bushel of soybeans.

Table 1.--Quantity and value relationship between soybean oil content and estimates of oil based on grade factors, by test sites, 1955 crop year 1/

Test site	Carload lots sampled	Relationship 2/	Accuracy of estimated oil content		Difference in value of oil
	Number	Degree	Percent 3/	Pounds 4/	Cents per bushel 5/
Ames, Iowa	191	0.681	±0.507	±0.304	±3.80
Decatur, Ill.	200	.762	±.452	±.271	±3.39
Des Moines, Iowa ...	184	.674	±.419	±.251	±3.14

1/ Laboratory-determined oil content expressed as a percentage of whole beans. Damage as a grade factor was not included in the analysis.
2/ Multiple correlation coefficient: The relationship between a dependent variable and two or more independent variables. Perfect relationship between oil content and the grade factors would be 1.
3/ Standard error of estimate. Approximately two-thirds of the oil content estimates made by using the regression equations would come within 0.51, 0.45, and 0.42 percentage points of the laboratory-determined oil content, depending on the area where the soybeans were grown.
4/ Pounds of oil per 60-pound bushel.
5/ Oil value based on 12.5 cents per pound, the average price of soybean oil (crude oil, f.o.b. Midwest mills) for the 1955-56 marketing year.

3/ Oil content was estimated by the use of multiple regression equations.

In 19 times out of 20 at the 3 test sites the differences between the estimates and the laboratory-determined oil content were within 0.64, 0.57, and 0.53 pounds of oil and in 99 times out of 100 cases the differences were within 0.88, 0.78, and 0.73 pounds of oil per 60-pound bushel.

Since more than one variety of soybeans was included in the study, some of the differences between the estimated and the laboratory oil content probably was due to inherited characteristics of the varieties and not entirely to the grade factors.

Differences in Soybean Oil Value, by Soybean Grades

Analysis of all the soybean samples obtained at the 3 test sites, and classified by grade, showed that the official grades tended to give some indication of the relative quantities of oil in the beans (table 2). Generally the higher grades were found to have a higher average oil content than the lower grades. These findings agree with those reported in a previous study. 4/ In 4 out of 11 cases, however, the average oil content of a given grade was less than that for the next lower grade, though these differences were small. Moreover, there was considerable variation in oil content within most grades, and consequently there was variation in the oil value of soybeans meeting the same grade requirements. The average of the variation of oil content within grades for the 3 sites ranged from about 1/3 of a pound of oil per 60-pound bushel for the sample grade to about $1\frac{3}{4}$ pounds of oil per bushel for grade No. 2. These variations in oil content within grades indicate the need for a more precise method of determining differences in oil content if a farmer is to receive payment for his soybeans that is more in line with their market value.

Processors generally rely on the grade factors to reflect the quantity and quality of products obtained from soybeans. Since September 1, 1955, they began buying soybeans on the basis of the No. 1 grade, and soybeans not meeting the requirements for No. 1 are discounted according to their individual grade factors.

Evaluating Soybeans by Use of the Rapid Dielectric Method

To determine the relative reliability of the dielectric method in measuring soybean oil content under local market conditions, the relationship between the oil content by dielectric measurement and the corresponding oil content determined at a commercial laboratory was obtained for 493 samples. Analysis of the paired sets of oil-content determinations showed that at the 3 test sites the relationship between the oil-content determinations by the dielectric and standard laboratory methods were 0.726, 0.603, and 0.585, respectively

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4/ Keirstead, C. H. Marketing Study of Factors Affecting the Quantity and Value of Products Obtained from Soybeans. U. S. Dept. Agr., Prod. and Mktg. Admin. 35 pp., 1952.

Table 2.--Quality and value relationships between average oil content of soybeans by grades, 1955 crop year

Test site and grade	Carlots sampled	Average oil content 1/	Difference in average oil content 2/		Difference in value of oil content 3/
	Number	Percent	Percent	Pounds per bushel	Cents per bushel
Ames, Iowa:					
No. 1	56	21.30	base	base	base
No. 2	104	20.93	-0.37	-0.222	-2.78
No. 3	20	20.66	-.64	-.384	-4.80
No. 4	9	20.09	-1.21	-.726	-9.08
S. G.	2	21.18	-.12	-.072	-.90
Decatur, Ill.:					
No. 1	37	21.94	base	base	base
No. 2	118	22.00	+.06	+.036	+.45
No. 3	29	21.60	-.34	-.204	-2.55
No. 4	12	21.00	-.94	-.564	-7.05
S. G.	4	21.21	-.73	-.438	-5.47
Des Moines, Iowa:					
No. 1	115	21.86	base	base	base
No. 2	59	21.80	-.06	-.036	-.45
No. 3	8	21.32	-.54	-.324	-4.05
No. 4	2	21.34	-.52	-.312	-3.90
S. G.	0	---	---	---	---

1/ Laboratory-determined oil content expressed as a percentage of dry matter.

2/ The oil content of No. 1 beans is used as a base and the difference in oil content of other grades is measured from this base. Weight of oil is based on a 60-pound bushel.

3/ Oil value at 12.5 cents per pound, the average price of soybean oil (crude oil, f.o.b. Midwest mills) for the 1955-56 marketing year.

(perfect relationship between the 2 sets of oil determinations would be equal to 1). While the above correlation values indicate the relationship between the two variables, they do not indicate the amount of difference between them. In 2 out of 3 cases the estimates obtained from the dielectric oil determinations came within 0.46, 0.50, and 0.40 percentage points, respectively, of the laboratory oil determinations (table 3). These percentage points of oil converted to weight per 60-pound bushel of soybeans represent differences of 0.27, 0.30, and 0.24 pounds of oil, respectively, between the 2 methods. If oil is

Table 3.--Quantity and value relationship between soybean oil content determined by the dielectric and commercial laboratory methods, 1955 crop 1/

Test site	Oil tests	Relationship 2/	Accuracy of estimated oil content		Difference in value of oil
	Number	Degree	Percent 3/	Pounds 4/	Cents per bushel 5/
Ames, Iowa	173	0.726	±0.455	±0.273	±3.41
Decatur, Ill.	176	.603	±.502	±.301	±3.76
Des Moines, Iowa ..	144	.585	±.404	±.242	±3.02

1/ Oil content expressed as a percentage of dry matter.

2/ Coefficient of correlation: The relationship between the two variables. Perfect relationship between the oil content results obtained by the two methods would be 1.

3/ Standard error of estimate. Approximately two-thirds of the estimates made by converting dielectric oil determinations by the regression equations would come within 0.46, 0.50, and 0.40 percentage points of the corresponding oil determinations obtained by the commercial laboratory, depending on the dielectric oil-tester used. The regression lines were plotted from the following regression equations for the 3 test sites: $y = 8.661 + 0.60384x$; $y = 14.045 + 0.34728x$; $y = 12.470 + 0.41077x$, respectively, where y = laboratory oil content (percentage) and x = dielectric oil content (percentage).

4/ Pounds of oil per 60-pound bushel.

5/ Oil value based on 12.5 cents per pound, the average price of soybean oil (crude oil, f.o.b. Midwest mills) for the 1955-56 marketing year.

worth 12.5 cents per pound, these would be equal to 3.4, 3.8, and 3.0 cents per bushel of soybeans. In 19 out of 20 cases at these 3 test sites the difference between the oil content determined by the 2 methods was within 0.54, 0.59, and 0.48 pounds of oil, respectively, and in 99 out of 100 cases the oil differences were within 0.71, 0.78, and 0.63 pounds of oil per 60-pound bushel.

For all 3 test sites the difference between the laboratory oil-test results and the estimates obtained from the dielectric oil determinations was similar to the difference between estimates of oil content by soybean grades and laboratory oil-test results. Moreover, the dielectric method provided percentage of oil content, not obtainable from the present method of estimating the market value of soybeans from the official grade factors.

Sources of Variation in the Dielectric Oil Content Determinations

Several factors can influence the oil content determined by use of the dielectric method. These include: Accuracy of weighing the samples, sharpness

of the cutter blade used in grinding samples, accuracy in measuring the solvent, temperature of the test cell and temperature of the solvent in the test cell, accuracy of moisture content readings for soybean samples, and adjustment and balance of the oil-tester.

For the 493 comparative tests run for this study, the dielectric oil determinations averaged 0.27 percentage point higher 5/ than the corresponding oil determinations from the laboratory. The dielectric oil-test results, however, were not all uniformly higher. The dielectric oil tests run at Ames, Iowa, averaged 0.58 percentage point of oil lower than the corresponding laboratory oil tests. At Decatur, Ill., and Des Moines, Iowa, the dielectric oil tests averaged 0.63 and 0.83 percentage points of oil, respectively, higher than the corresponding laboratory oil tests.

Analysis of the data for all 3 test sites indicated that 45.1 percent of the variation in differences between the dielectric and the laboratory oil determinations was due to variation among the 3 test sites. This variation among the test sites could have resulted from adjustments of the 3 dielectric oil-testers, possible difference in average temperature of the test cells and solvent, and/or the attention given to details of testing procedure at the 3 locations.

Changing a cutter blade (after grinding 112 samples) for a new cutter blade on the grinding mill at the Decatur test site accounted for 0.8 percent of the variation in the oil content determined by the 2 methods.

A tendency for the dielectric oil determinations to drift downward at the Ames test site and upward at the Des Moines site accounted for 22.6 percent of the variation. These drifts suggest the possibility of a gradual change in the electronic balance of the oil testers together with a difference in the relative dulling of the cutter blades used in grinding the samples.

At the Ames and Des Moines test sites there was a tendency for the first sample run each testing day to show significantly lower oil content than the remaining samples tested in series. This accounted for 1.1 percent of the difference. This could have been due to insufficient warming up of the test cell or to improper cleaning of the test cell allowing a residual film of oil to remain on the cell wall surfaces from one testing day to the next.

About 70 percent of the total variation in the differences between the oil content obtained by the dielectric and standard laboratory methods was due to these four sources of variation leaving about 30 percent of the variation unexplained. After these 4 sources of variation were statistically removed, in 2 out of 3 cases the difference between the oil content determined by the dielectric and the standard methods was within 0.516 in terms of percentage of oil or 0.31 pound of oil per 60-pound bushel. In 99 times out of 100 this difference would be within 1.33 percentage point or 0.80 pound of oil.

5/ The standard error of the average difference was within ±0.1084 percentage point of oil in 99 times out of 100.

Improving Dielectric Oil-Test Results

Greater accuracy can be obtained by making repeat runs per sample. If 4 repeat runs per sample were made, the above difference in oil content determined by the 2 methods could be reduced, in 2 times out of 3, to 0.26 percentage point or 0.16 pound of oil. In 99 times out of 100 the difference would be within 0.66 percentage point or 0.40 pound of oil if 4 repeat runs per sample were made. Consequently, if 4 dielectric oil tests were run per sample from a farmer's lot of soybeans, a much more accurate determination of oil content for the lot could be achieved.

Some variation in oil-content determinations for a given sample of soybeans can be expected even when the official method of the American Oil Chemists' Society is used by Government-approved chemists. A comparison of soybean oil-content determinations obtained by 23 approved chemists and those determined by referee chemists for 50 or more soybean check samples showed that for an average of 57 percent of the oil determinations the variation was within 0.2 percentage point of oil. An average of 15 percent of the determinations showed a variation of between 0.2 and 0.3 in terms of percentage of oil. The average variation for the remaining 28 percent of the determinations was somewhat greater than 0.3. 6/

Comparison of the dielectric and laboratory oil test data obtained during the first year of this study indicates that the relative efficiency of the dielectric tester can change over time. Therefore, the tester should be checked regularly for proper operation and adjustments made as necessary to maintain efficiency. The cutter blade used in grinding samples should be kept sharp to provide uniform consistency of the ground sample for testing.

The dielectric method has an advantage in that nontechnical personnel, after receiving brief instructions, can operate the grinding mill and test equipment under field conditions. However, it is extremely important that they follow the instructions very closely as any deviation from them can adversely affect the results obtained.

6/ Doughtie, R. T., Jr. Comparison of Performances of Approved Chemists Handling Commodity Credit Corporation-Processor Soybean Analysis Work During the Seasons of 1944-45 and 1945-56. Jour. Amer. Oil Chemists' Soc. 24(8): 265-269. 1947.